

USING GENETICS AND MORPHOLOGY TO EXAMINE SPECIES DIVERSITY OF OLD WORLD BATS: REPORT OF A RECENT COLLECTION FROM MALAYSIA

FAISAL ALI ANWARALI KHAN, VICKI J. SWIER, SERGIO SOLARI, PETER A. LARSEN, BESAR KETOL, WAHAP MARNI, SIVANATHAN ELLAGUPILLAY, MAKLARIN LAKIM, MOHAMMAD TAJUDDIN ABDULLAH, AND ROBERT J. BAKER

ABSTRACT

A three-week field survey was conducted to sample bat species diversity in Malaysia. The survey sampled five localities during August 2006, including one in Peninsular Malaysia and four in Borneo. A total of 259 specimens representing at least 50 species were recorded. Three sampling nights were spent at each locality; four harp traps and 15 mist nets were set most nights. The highest species diversity was recorded in Mount Penrisen (Borneo) with 27 species, whereas the lowest diversity was at Monggis Sub Station and Bako National Park (Borneo) with 13 species each. We added four new geographic records for Sarawak, Malaysian Borneo: *Arielulus cuprosus*, *Hesperoptenus tomesi*, *Kerivoula lenis*, and *Myotis adversus*; and the second record of *Hipposideros doriae* in Sarawak. Other findings included a colony of earwigs collected from an *Eonycteris major* and the documentation of highly developed facial glands on male *Hipposideros ater* and *H. galeritus*. Species were identified using traditional skin and skull characteristics as well as mitochondrial cytochrome-*b* gene sequences that were compared to existing GenBank records. This multifaceted approach, using genetic and morphological identifications, has provided greater resolution to species identification as well as a better understanding of the diversification of Old World Bats from Malaysia. Although in most cases genetic data validated the present taxonomy, there were still a number of cases of cryptic species suggesting an underestimation of the actual biodiversity. This study has demonstrated the value of genetic data in providing an independent test for species boundaries among the 50 species of bats collected (about 40% of the known Malaysian bat fauna).

Key words: Borneo, Chiroptera, cytochrome-*b*, diversification, Peninsular Malaysia

INTRODUCTION

The first faunal list of bats from Malaysia (including Peninsular Malaysia, Sabah, and Sarawak) was published by Chasen (1940) and contained 84 species. Several subsequent compilations listing the Malaysian chiropteran fauna were published, each with alternative numbers of bat species (80 spp. in Malaysia and Singapore, Medway 1969; 92 spp. in Borneo, Payne et al. 1985; 307 spp. within the Indomalayan range, Corbet and Hill 1992). The most recent taxonomic synthesis identified 125 species with Malaysian distributions (Simmons 2005).

Comparing the number of species compiled within these faunal lists provides insight into the advance-

ment of capture techniques (e.g., harp traps; Francis 1989), and the resolving power (to delimit species) of methodologies and species concepts for species recognition (e.g., DNA sequencing: Avise and Walker 1999; Bradley and Baker 2001; Baker and Bradley 2006). Given this, it is clear that an integrated approach using morphology and genetics has the potential to provide better resolution of species and species boundaries (e.g., Francis et al. 2007; Mayer et al. 2007). It is effective to incorporate these methods into field surveys aimed at describing species diversity.

We assigned species level names to our specimens through comparison of morphology to published spe-

cies descriptions, as well as by comparing the sequences of a portion of the mitochondrial cytochrome-*b* gene to those deposited in GenBank.

Herein, we report our results for the 2006 Malaysian Sowell Expedition. Since 2001, Mr. James E. Sowell has funded expeditions to enhance the natural

history collections of the Texas Tech University Museum, with a focus on mammals and genomic resources. A goal of these expeditions was to provide students an educational experience through hands-on scientific studies as well as exposure to unique ecosystems and cultures (see inside front cover).

MATERIALS AND METHODS

Sampling sites.—The expedition by Texas Tech University (TTU) and the Universiti Malaysia Sarawak (UNIMAS) to Peninsular Malaysia and Borneo was conducted from 3 to 19 August 2006. Sampling localities (Fig. 1) are as follows:

Krau Wildlife Reserve, Pahang, Peninsular Malaysia (03°35'45.6"N, 102°10'54.2"E; elevation 72 m; 3-6 August).—This is likely the most extensively studied site for bat diversity in Peninsular Malaysia (e.g., Zubaid 1993; Hodgkison 2001; Campbell 2004; Kingston et al. 2006) as it is part of a large research site maintained by the Department of Wildlife and National Parks (DWNP). This locality is reported to have the highest diversity of insectivorous bats in the tropics, with more than 52 species from a single 3 km² area surrounding the Kuala Lompat field station (Kingston et al. 2006). In total, there are at least 69 species of bats in the reserve. Our study site consisted mainly of undisturbed dipterocarp forest and a small stream.

Monggis Sub Station of Kinabalu National Park, Sabah, Malaysian Borneo (06°12'1.5"N, 116°45'7.5"E; elevation 330 m; 7-10 August).—This research station is an extension of Kinabalu National Park that was not open to visitors at the time of our survey. Our sampling was part of a collaborative work between the Kinabalu Park management and UNIMAS to provide a checklist of small mammals that occur in the vicinity of the station. The majority of this site consisted of mixed dipterocarp forest with intermittent thickets of bamboo and small streams.

Bako National Park, Sarawak, Malaysian Borneo (01°42'59.5"N, 110°26'39.3"E; elevation 8 m; 11-13 August).—Established in 1957, Bako National Park

is the oldest national park in Sarawak. It is located 37 km northeast of Kuching city and includes 27 km² of the Muara Tebas Peninsula. This park is bordered to the north by the South China Sea with the coastline providing secluded beaches and rock formations. Bako National Park is home to at least 34 species of bats (Anwarali et al. 2007). Seven different vegetation types are present: mixed dipterocarp forest, riverine or alluvial forest, heath forest, mangrove forest, beach vegetation, cliff vegetation, and shrubland (Hazebroek and Abang Kashim 2000).

Kubah National Park (Kubah NP), Sarawak, Malaysian Borneo (01°36'42.3"N, 110°26'39.3"E; elevation 8 m, 14-16 August).—This park is located approximately 22 km southeast of Kuching city and covers about 22 km². Mount Serapi (911 m) is Kubah's highest point. Kubah is widely covered by mixed dipterocarp forest and is well known for its frog pond, which includes a high diversity of frog species (Hazebroek and Abang Kashim 2000). This small stagnant pond was one of our major mist netting sites.

Mount Penrisen, Sarawak, Malaysian Borneo (01°07'41.4"N, 110°13'06.7"E; elevation 857 m, 17-19 August).—Mount Penrisen, locally known as Borneo Heights and located within the Padawan district, is approximately 70 km south of Kuching. This site was the highest elevation surveyed during our expedition. Most of the vegetation at Penrisen was covered by primary mixed dipterocarp forest with patches of secondary forest (near cleared areas for logging and road construction purposes). Our two major collecting sites at this location were near the edge of a newly developed golf course and within the primary forest located on a plateau near the Sarawak-Kalimantan border.

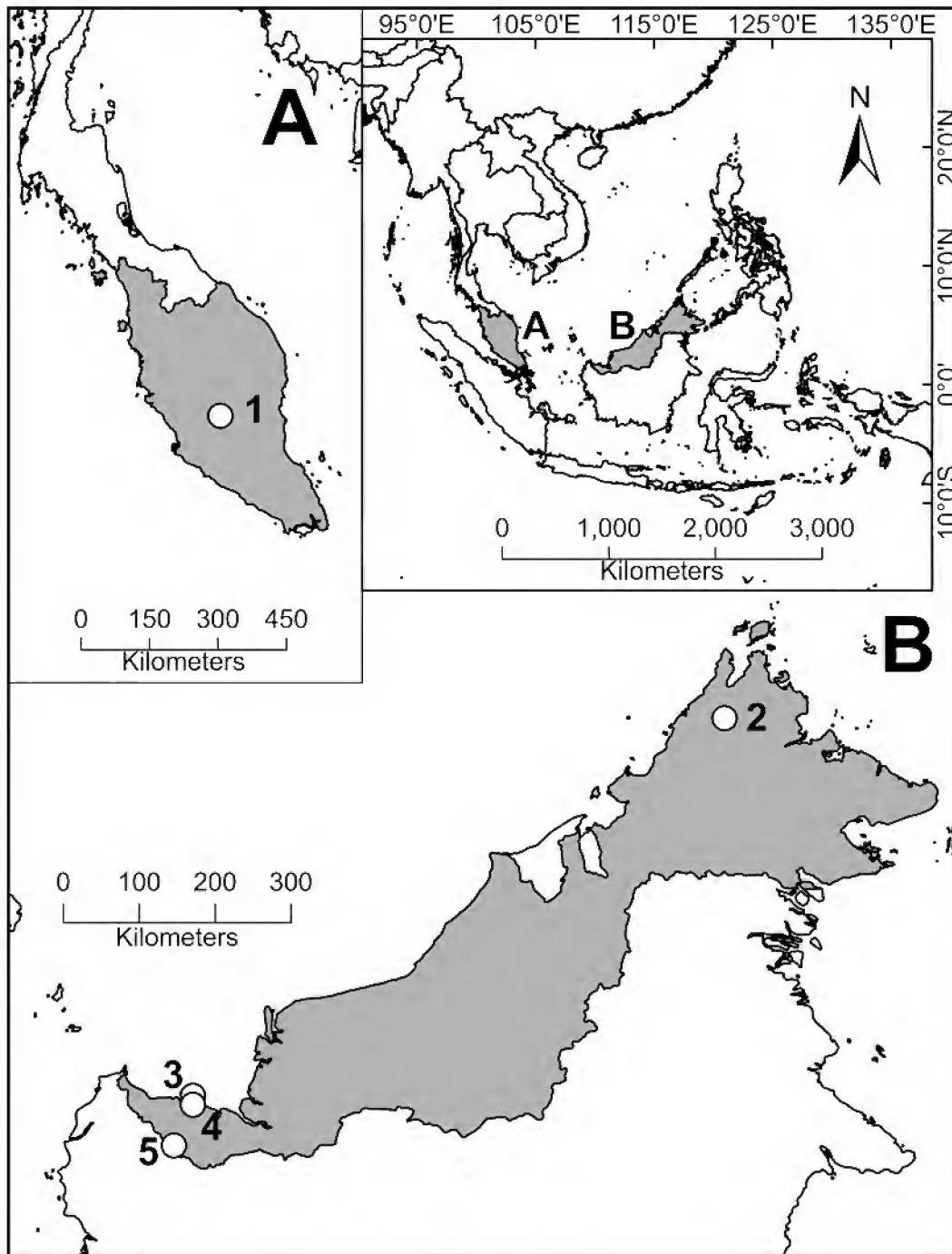


Figure 1. Map in upper right corner showing South East Asia with Peninsular Malaysia (A) and Malaysian Borneo (B) in gray. The five collecting localities described herein are Peninsular Malaysia: 1 = Krau Wildlife Reserve; and Malaysian Borneo: 2 = Monggis Sub Station; 3 = Bako National Park; 4 = Kubah National Park; 5 = Mount Penrisen.

Field methods.—Fifteen mist nets (2, 6, 9, 12, and 30.5 m long) and four sets of four-bank harp traps were set most nights. Nets and traps were set by 1730 h, and closed between 0200 h and 0700 h the following day. Nets were checked every 20 minutes during the first six hours, and then checked every 2–3 hours before closing them the next day. Harp traps were checked three to four times each night. Scoop, hand nets, and short nets (2 m) were used to collect specimens at several roosting locations, especially within culverts.

Specimens were identified in the field following identification keys by Payne et al. (1985), Corbet and Hill (1992), and Kingston et al. (2006). After assigning species identification, three individuals per species were taken as voucher specimens. An additional three specimens were collected for species that exhibited substantial morphological variation suggesting more than a single species existed within the sampled population. Standard measurements were taken from each individual, which was then prepared as a museum voucher specimen, either as a skin and skeleton or as a fluid preserved specimen. Tissue samples from liver and muscle were preserved in lysis buffer (Longmire et al. 1997) and 95% ethanol, and blood samples were collected using Nobuto blood filter strips (Advantec Inc.). Phoretic insects and ectoparasites found on the specimens were preserved in 70% ethanol. Karyotypes were prepared in the field (Baker et al. 2003) for individuals from each species. Animals were handled following the standards of the American Society of Mammalogists (Gannon et al. 2007) and the Texas Tech Animal Care and Use Committee (Permit # 02217-02). Voucher specimens and duplicates of tissue samples (liver and muscle) were deposited in the Natural Science Research Laboratory, Museum of Texas Tech University (NSRL-TTU), Natural History Museum of Universiti Malaysia Sarawak (UNIMAS), Institute of Biological Diversity, Bukit Rengit, Pahang (IBD), and Kinabalu National Park (Kinabalu NP).

Molecular methods.—Methodology for DNA extraction and Polymerase Chain Reaction (PCR) followed Larsen et al. (2007). The entire cytochrome-*b* (*cyt-b*) gene was amplified using primer pair L14724-H15915r (Irwin et al. 1991). The optimized annealing temperature for each bat family was determined using gradient PCR at the following temperatures: 40.2°C (Rhinolophidae, Vespertilionidae), and 50.0°C (all

other families). PCR products were purified using the QIAquick PCR Purification Kit (Qiagen Inc., Chatsworth, California). DNA sequencing was performed using ABI Big Dye chemistry chain terminators version 3.1 and fragments were electrophoresed on an ABI 3100-Avant Genetic Analyzer (PE Applied Biosystems, Foster City, California). The first 404 or 450bp of the *cyt-b* gene were sequenced in this study using L14724 (Irwin et al. 1991) and the internal primer MVZ04 (Smith and Patton 1993). Additionally, we used three internal primers: HF041 (5'-CCT-CAR-AAR-GAT-ATT-TGG-CCT-CAT-GG-3') for the genera *Eonycteris*, *Penthetor*, *Rhinolophus*, and *Emballonura*; HF042 (5'-RAA-RGA-YAT-YTG-TCC-TCA-TGG-3') for *Hipposideros* and *Megaderma*; and EPH520 (5'-RAA-KGG-GAG-TAG-AAA-GTG-GAA-GGC-3') for species of Vespertilionidae and *Miniopterus* as alternative primers for MVZ04 (Smith and Patton 1993).

Validating field identifications.—Field identifications of specimens were re-evaluated using skin and skull characteristics which were compared to published descriptions as well as *cyt-b* gene sequences. Sequences were viewed in a Neighbor Joining (NJ) tree to confirm the genetic distinction of each species as well as to assess variation among conspecifics through genetic distances. Genetic distances were calculated following the Kimura 2-parameter model using MEGA software version 4.0 (Kumar et al. 2004). Specimens identified as conspecifics that exhibited high genetic divergences ($\geq 5\%$), were further verified by examining external and cranio-dental characters (e.g., Payne et al. 1985; Corbet and Hill 1992; Francis 2008). This combination of data allowed the documentation of the genetic variation within putative species identified using morphology, an operational method suggested for application of the Genetic Species Concept (see Bradley and Baker 2001; Baker and Bradley 2006). Under this operational method, a genetic distance of $\geq 5\%$ in the *cyt-b* gene is used as an indicator for speciation events because many sister species of mammals described based on morphological variation have $\geq 5\%$ genetic distance value. We interpret this as indicating that a $\geq 5\%$ genetic distance value for the cytochrome-*b* gene sequence data documents that two clades may have been isolated from each other for sufficient time to have speciated by the Bateson-Dobzhansky-Muller model (Baker and Bradley 2006). We provide GenBank accession numbers for representatives of each species

reported herein. Genetic divergences associated with geographic variation between Peninsular Malaysia and Bornean specimens are discussed briefly, as detailed

phylogenetic and phylogeographic analyses will be provided in subsequent publications.

SPECIES ACCOUNTS

Species accounts were compiled using various published data as well as UNIMAS, DWNP, and Southeast Asian Mammal Databank databases (Biotani et al. 2006). Natural history and species designations presented herein were reviewed for each species based primarily on the data derived from our identifications. Unless otherwise noted, the taxonomic arrangement herein follows Simmons (2005). Main departures from that work include Csorba et al. (2003) for Rhinolophidae and Hofer and Van Den Bussche (2003) for Vespertilionidae, including the recognition of the family Miniopteridae. Common names in English were from Simmons (2005) whereas Malay names were from Medway (1969) and Khan (1992), and are included in parentheses. Information was organized into the following categories:

Specimens examined.—Total number of specimens examined given in parentheses, followed by locality and TTU catalogue numbers (for voucher specimens, tissues, and karyotypes that are deposited at NSRL) or TK numbers (for tissues and karyotypes at NSRL but voucher specimens deposited at IBD, Kinabalu NP, or UNIMAS). For each species, a GenBank accession number was assigned to one specimen (in parentheses following a TTU or TK number).

Type locality.—The known type locality of species according to country, region, state (if available), and specific locality (if available) is described.

Malaysian distribution.—Species distribution in Malaysia is described in the following order: country, region, state (if available) and specific locality (if available). State and specific localities are not provided for species that are widely distributed either in Peninsular Malaysia or Borneo. We provided specific localities for those species that do not have many collection records, and specific localities for those species with new records from this study to assist in future faunal surveys. Distribution in Malaysia was retrieved from the following sources: Lim et al. (1974), Payne et al.

(1985), Corbet and Hill (1992), Abdullah et al. (1997; 2003), Yasuma and Andau (2000), Csorba et al. (2003), Hall (2004), Kingston et al. (2006), Francis (2008), Southeast Asian Mammal Databank (SAMD), unpublished UNIMAS Museum records, and unpublished DWNP specimen records.

Remarks.—Species group or tribe was noted when available. Key diagnostic features that distinguish the species from similar congeners, the type of traps used, and collecting habitats (also derived from Payne et al. 1985; Corbet and Hill 1992; Csorba et al. 2003; Kingston et al. 2006; Francis 2008) are included in this section. Other information involving genetics and/or morphology was included where appropriate. Status of reproduction for females was: lactating, post lactating, with embryo (pregnant), or carrying a juvenile. The following abbreviations were used: FA = forearm; Mt. = Mount; and NP = National Park.

Family Pteropodidae

Aethalops aequalis G. M. Allen 1938 Borneo Fruit Bat (Cecadu Bukit)

Specimens examined (5).—Mt. Penrisen: TTU 108348 (GenBank EU521595), TTU 108352, TTU 108357, TTU 108409, TTU 108381.

Type locality.—Malaysia (Borneo), Sabah, Mount Kinabalu.

Malaysian distribution.—Recorded from highlands in Sabah and Sarawak. Specimens were collected from Mt. Penrisen in this study.

Remarks.—*Aethalops aequalis* is commonly found at higher elevations in hill and mountain forests (Payne et al. 1985). This species was caught using mist nets across small streams. Compared to other fruit bats, *A. aequalis* is fragile and requires careful handling and quick release if it is not to be prepared as a voucher specimen. This species was previously

recognized as *Aethalops alecto* (Payne et al. 1985). Studies (Kitchener et al. 1993) suggest that only Peninsular Malaysia populations, as well as Sumatra, Java, Bali, and Lombok populations, should be recognized as *alecto* (Pygmy Fruit Bat) whereas Borneo populations are referable to *aequalis*. Although morphological characters differentiate *aequalis* from *alecto*, allozymic variation between them is low (see Kitchener et al. 1993). Cytochrome-*b* gene sequences within our sample from Borneo averaged 0.2%. Pending genetic data from Peninsular Malaysia populations as well as specimens from Sabah, we follow Kitchener et al. (1993) for geographic boundaries of *A. alecto* and *A. aequalis*.

Balionycteris maculata (Thomas 1893)
Spotted-winged Fruit Bat (Cecadu Sayap Bertitik)

Specimens examined (7).—Bako NP: TTU 108265 (GenBank EU521596), TTU 108266, TTU 108299; Kubah NP: TTU 108312, TTU 108317, TTU 108321; Mt. Penrisen: TTU 108364.

Type locality.—Malaysia (Borneo), Sarawak.

Malaysian distribution.—Recorded from Borneo.

Remarks.—*Balionycteris maculata* is the smallest fruit bat in Borneo (FA: 40–45 mm; weight: 10–15 g). This species was caught using mist nets near rock cliffs in mangrove forests, over ponds, and in open areas near hill edges. A diagnostic feature of this bat is the obvious white to pinkish spots on its wings. These frugivorous bats are commonly found in lowland dipterocarp forest and occasionally at higher elevations. Two subspecies, *B. maculata seimundi* and *B. maculata maculata*, have been recognized in Peninsular Malaysia and Borneo, respectively (Kloss 1921), a taxonomic arrangement followed by many authors (e.g., Payne et al. 1985; Hodgkison and Kunz 2006; Francis 2008). We found a genetic distance of 12% in the *cyt-b* gene sequences between populations in Borneo and Peninsular Malaysia. Following application of the 5% species level separation proposed by Baker and Bradley (2006), and the morphological variation between Kalimantan (Indonesian Borneo) and Sumatra (Indonesia) populations (Maryanto 2003), we recognize these populations as separate species.

Balionycteris seimundi (Kloss 1921)
Malayan Spotted-winged Fruit Bat
(Cecadu Sayap Bertitik Malaya)

Specimens examined (2).—Krau: TK 152011 (GenBank EU521597), TTU 108175.

Type locality.—Malaysia (Peninsular Malaysia), Pahang, Gunung Tahan.

Malaysian distribution.—Recorded from Peninsular Malaysia (all states).

Remarks.—*Balionycteris seimundi* represents the smallest fruit bat of Peninsular Malaysia (FA: 39–43 mm; weight: 13–14.1 g). We propose that the common name for this species be the Malayan Spotted-winged Fruit Bat in English and Cecadu Sayap Bertitik Malaya in Malay. See *B. maculata* species account for details.

Cynopterus brachyotis Müller 1838
Lesser Short-nosed Fruit Bat (Cecadu Pisang)

Specimens examined (18).—Monggis: TTU 108245 (GenBank EU521598), TTU 108246, TK 152094, TTU 108247, TTU 108248, TTU 108257, TTU 108258, TTU 108259; Bako NP: TTU 108280; Kubah NP: TTU 108320, TTU 108323, TTU 108324, TTU 108330, TTU 108338; Mt. Penrisen: TTU 108411, TTU 108401, TTU 108402, TTU 108382.

Type locality.—Dewei River in Borneo, also known as Tewe River in Naga Cave.

Malaysian distribution.—Recorded from Peninsular Malaysia and Borneo from sea level to 1600 m.

Remarks.—*Cynopterus brachyotis* was netted mainly in primary forest, secondary forest, and agricultural areas. We identified two forms (large FA: 60–68 mm; small FA: 54–59 mm) of *C. brachyotis* (reported in Abdullah 2003; Campbell et al. 2004), but these size groups were not congruent with mitochondrial DNA data. The level of *cyt-b* genetic distances within Peninsular Malaysia (10.3%) and Borneo (9.5%) suggested two independent lineages; however, both genetic lineages include individuals that overlap in forearm sizes.

Cynopterus horsfieldii Gray 1843
Horsfield's Fruit Bat (Cecadu Pisang Besar)

Specimens examined (9).—Krau: TK 152002 (GenBank EU521599), TK 152003, TTU 108170, TTU 108212, TTU 108214, TTU 108215, TK 152058, TTU 108223, TTU 108224.

Type locality.—Indonesia, Java.

Malaysian distribution.—Recorded from Peninsular Malaysia (all states) and Borneo from sea level to 1400 m.

Remarks.—This species was caught using mist nets at Krau across forest trails. In Borneo, *C. horsfieldii* was captured at high elevations (900 m) in primary forest (Jayaraj et al. 2005; 2006). Forearm length (68–76 mm) is a good character to separate this species from *C. brachyotis* in the field (Payne et al. 1985). Unlike *C. brachyotis*, there is low *cyt-b* genetic distance (2%) observed within and between Peninsular Malaysian (samples from this study) and Bornean (samples from UNIMAS museum collections) individuals. Habitats where *C. horsfieldii* occurs in Borneo should be given high conservation priority, as this species is rare or at least not commonly reported when compared to Peninsular Malaysia samples. Two of four adult female specimens were pregnant: TK 152002 (3 August 2006) and TK 152058 (6 August 2006); and two were carrying young: TK 152003 (6 August 2006) and TTU 108223 (7 August 2006).

Eonycteris major K. Andersen 1910
Greater Dawn Bat (Cecadu Gua Besar)

Specimens examined (4).—Kubah NP: TTU108327 (GenBank EU521600); Mt. Penrisen: TTU 108371, TTU 108372, TTU 108410.

Type locality.—Malaysia (Borneo), Sarawak, Mount Dulit.

Malaysian distribution.—*Eonycteris major* is endemic to Borneo.

Remarks.—The genus *Eonycteris* is distinguished from all other fruit bats by the lack of a claw on the sec-

ond digit of the wing. We caught *Eonycteris major* at Kubah NP in a net placed in front of a banana tree, and in Mt. Penrisen this species was caught at the edge of a steep cliff where bats were flying near stands of banana trees. This species is the largest nectar-feeding bat in Malaysia, with a long muzzle that is slender and curved. *Eonycteris major* also has an enlarged gland near the anus. Forearm length distinguishes *E. major* (71–80 mm) from the smaller *E. spelaea* (62–70 mm; Payne et al. 1985). Both of these species roost in limestone caves (SAMD database). Low *cyt-b* genetic distance (0.1%) was observed among Bornean individuals. A specimen, TTU 108410 (18 August 2006; Mt. Penrisen), was carrying earwigs (*Scizochelisochea* sp.; Fig. 2) on its dorsum near the base of the tail. This is the first record for earwigs on this bat species. Specimens of these earwigs are housed in the NSRL.

Eonycteris spelaea (Dobson 1871)
Lesser Dawn Bat (Cecadu Gua Kecil)

Specimens examined (7).—Krau: TK 152009 (GenBank EU521601), TTU 108211; Monggis: TTU 108240, TK 152091; Mt. Penrisen: TTU 108373, TTU 108378, TTU 108387.

Type locality.—Burma, Tenasserim, Moulmein, Farm Caves.

Malaysian distribution.—Recorded from the lowlands of Peninsular Malaysia (all states) and Borneo.

Remarks.—We netted this species near banana trees. *Eonycteris spelaea* can be distinguished from their larger counterpart *E. major* by forearm length and shorter muzzle size (see *E. major* species account). Like *E. major*, this species also has an enlarged external gland lateral to the anus. *Eonycteris spelaea* is distributed throughout most of Southeast Asia and often found in colonies of thousands in caves within agricultural areas (McClure et al. 1967; Heaney et al. 1989). Genetic distance value of < 0.8% was observed within Peninsular Malaysia and Borneo individuals, whereas genetic distance value of 1% was observed between Peninsular Malaysia and Borneo individuals. A pregnant female, TK 152085 (8 August 2006), was recorded with an embryo length of 31 mm.



Figure 2. The dorsal rump of a female *Eonycteris major* (TTU 108410) with a colony of earwigs (Order: Dermaptera: Chelisochidae; *Scizochelisoche* sp.). The tail of the bat is visible in the upper right quadrant of the photo.

Macroglossus minimus (E. Geoffroy 1810)

Dagger-toothed Long-nosed Fruit Bat
(Cecadu Madu Bakau)

Specimens examined (11).—Monggis: TTU 108225 (GenBank EU521602), TTU 108226, TK 152070, TK 152071, TTU 108227, TTU 108231, TTU 108232; Mt. Penrisen: TTU 108350, TTU 108366, TTU 108374, TTU 108376.

Type locality.—Indonesia, Java.

Malaysian distribution.—Recorded from both Peninsular Malaysia (all states) and Borneo.

Remarks.—*Macroglossus minimus* and *M. sobrinus* were netted near banana trees and in most cases they

were caught alongside *C. brachyotis*. *Macroglossus minimus* can be morphologically distinguished from *M. sobrinus* by the absence of a median groove in the upper lip, and its smaller FA length (FA < 42 mm vs. FA > 42 mm; Payne et al. 1985; Francis 2008). Recent literature and SAMD database indicate *M. minimus* occurs throughout Southeast Asia, whereas *M. sobrinus* is restricted to Peninsular Malaysia, Sumatra, and Java. Low *cyt-b* genetic distance (1%) was observed within Bornean populations of *M. minimus*. A specimen, TTU 108366 (male), from Mt. Penrisen, Borneo, was identified as *M. minimus* based on the absence of a median groove in the upper lip and FA = 42 mm. This individual is genetically closer to *M. sobrinus* rather than *M. minimus*. Genetic distance between *M. minimus* (Borneo) and *M. sobrinus* (Peninsular Malaysia) averaged 2% and was the lowest for any sister species

relationship within our data for the family Pteropodidae from Malaysia. Although they may represent two species, a genetic distance value of 2% is typical for conspecific bat populations (Bradley and Baker 2001; Baker and Bradley 2006) and we question the recognition of these geographically isolated populations as distinct species. Three of our five female specimens were pregnant; TK 152070 (7 August 2006), TTU 108231 (7 August 2006), and TTU 108350 (17 August 2006).

Macroglossus sobrinus K. Andersen 1911
Greater Long-nosed Fruit Bat (Cecadu Madu Bukit)

Specimens examined (4).—Krau: TTU 108174 (GenBank EU521603), TK 152047, TTU 108206, TTU 108207.

Type locality.—Malaysia (Peninsular Malaysia), Perak, Gunung Igari (Mount Igari; 610 m).

Malaysian distribution.—Recorded from Peninsular Malaysia (all states).

Remarks.—*Macroglossus sobrinus* can be distinguished from their smaller counterpart *M. minimus* by larger forearm length, body size, and presence of median groove in the upper lip (see *M. minimus* species account for details).

Megaerops ecaudatus (Temminck 1837)
Temminck's Tailless Fruit Bat
(Cecadu Tiada Berekor)

Specimens examined (4).—Mt. Penrisen: TK 152245 (GenBank EU521604), TTU 108349, TTU 108412, TTU 108413.

Type locality.—Indonesia, West Sumatra, Padang.

Malaysian distribution.—Recorded from Peninsular Malaysia (all states) and Borneo.

Remarks.—*Megaerops ecaudatus* can be netted from lowland as well as mountain forests (Hodgkison 2004). The external morphology of this species is similar to *Cynopterus* and *Penthetor* but with an absence of a tail in *Megaerops*. Other diagnostic characters include tubular nostrils and absence of white edged

ears. *Megaerops ecaudatus* has low *cyt-b* genetic distance within our Borneo samples (<2%). Comparison of DNA sequences with others from GenBank showed high genetic distances (7% and 11%) between Peninsular Malaysian (EF105533) and Bornean (EF105536; Mount Murud) *cyt-b* sequences, suggesting the presence of two species.

Penthetor lucasi (Dobson 1880)
Lucas's Short-nosed Fruit Bat
(Cecadu Hitam Pudar)

Specimens examined (10).—Bako NP: TTU 108284 (GenBank EU521605), TTU 108287; Kubah NP: TTU 108313, TTU 108318, TTU 108319, TTU 108322, TTU 108329, TTU 108346; Mt. Penrisen: TTU 108363, TTU 108377.

Type locality.—Malaysia (North Borneo), Sarawak.

Malaysian distribution.—Recorded from Peninsular Malaysia and Borneo.

Remarks.—*Penthetor lucasi* was netted near rock crevices (Bako NP and Mt. Penrisen) and ponds (Kubah NP). We verified the occurrence of this species at an elevation (857 m) higher than the previously reported upper limit of 600 m (Payne et al. 1985; Jayaraj et al. 2006). Within our sample there appears to be two genetically distinct clusters with about 5% genetic divergence, indicating separate lineages. Sequences in GenBank (EF105541-EF105544) referred as *Penthetor lucasi* from Peninsular Malaysia and Borneo do not cluster with our sequences (25-27% genetic divergence), suggesting misidentification as they are closer to our *Macroglossus* sequences (2-4% genetic divergence). One of 10 adult female specimens, TTU 108313 (14 August 2006), was post lactating.

Family Rhinolophidae
Rhinolophus affinis Horsfield 1823
Intermediate Horseshoe Bat (Kelawar Ladam Hutan)

Specimens examined (4).—Mt. Penrisen: TTU 108353 (GenBank EU521607), TTU 108360, TTU 108361, TTU 108362.

Type locality.—Indonesia, Java.

Malaysian distribution.—Recorded from Peninsular Malaysia (all states) and Borneo.

Remarks.—*Megaphyllus* species group (Csorba et al. 2003). *Rhinolophus affinis* is distinguished from other similar species (*R. ferrumequinum*, *R. rouxi*, and *R. sinicus*) by the broadly rounded connecting process, as well as the tall and triangular noseleaf with a straight-sided lancet (Csorba et al. 2003; Francis 2008). All of our specimens were caught using harp traps along a forest trail. Coloration for this cave dwelling species ranges from bright orange to brown. Bright orange facial color on the rostrum was thought to be a diagnostic character for this species but after examination of several other specimens with similar noseleaf characters and measurements, we concluded that the orange pelage represented intraspecific variation. Approximately 4% in *cyt-b* genetic distance was observed between Bornean individuals from this study and a single individual from Thailand (TK 2116).

***Rhinolophus borneensis* Peters 1861**

Bornean Horseshoe Bat (Local name not available)

Specimens examined (5).—Monggis: TTU 108228 (GenBank EU521608); Kubah NP: TTU 108308; Mt. Penrisen: TTU 108385, TTU 108388, TTU 108393.

Type locality.—Malaysia (Borneo), Sabah, Labuan Island.

Malaysian distribution.—Recorded from Peninsular Malaysia (Perlis, Kampung Juara, and Tioman Island) and Borneo.

Remarks.—*Megaphyllus* species group (Csorba et al. 2003). *Rhinolophus borneensis* is distinguished from other similar species (*R. stheno*, *R. celebensis*, and *R. malayanus*) by its larger forearm size, narrower anterior swellings of upper skull, and the median septa of its lancet being wider than the middle pocket (Csorba et al. 2003; Francis 2008). In Kubah NP, we netted these bats near a small frog pond and also found them roosting inside a culvert. Orange and brown color forms were present within our specimens. *Rhinolophus borneensis* can be distinguished easily in Borneo as they do not occur in sympatry with species of similar external morphology such as *R. stheno* or *R.*

malayanus. Despite a wide distribution, *R. borneensis* is locally rare in Peninsular Malaysia when compared to Borneo (SAMD). Low *cyt-b* genetic distance (0.3%) was observed within Bornean populations.

***Rhinolophus luctus* Temminck 1834**

Woolly Horseshoe Bat (Kelawar Ladam Terbesar)

Specimens examined (6).—Kubah NP: TTU 108342 (GenBank EU521609), TTU 108343, TTU 108345; Mt. Penrisen: TTU 108407, TTU 108408, TTU 108395.

Type locality.—Indonesia, Java, Tapos.

Malaysian distribution.—Recorded from Peninsular Malaysia (all states) and Borneo. Our record is the second record for Mt. Penrisen after Medway (1977).

Remarks.—*Trifolius* species group (Csorba et al. 2003). In Kubah NP, this species was found roosting inside a culvert, alongside individuals of *R. sedulus*; whereas in Mt. Penrisen they were caught within a forest along a cliff edge. *Rhinolophus luctus* is the largest species of horseshoe bat in Malaysia with forearm size of 63-67 mm (Francis 2008).

***Rhinolophus philippinensis* Waterhouse 1843**

Large-eared Horseshoe Bat
(Local name not available)

Specimens examined (2).—Mt. Penrisen: TTU 108359 (GenBank EU521610), TTU 108380.

Type locality.—Philippines, Luzon.

Malaysian distribution.—Recorded from Borneo (Sabah: Gomantong Cave, Madai Caves, Sapulut, and Tapadong Cave; Sarawak: Bintulu, Lobang, Long Lama, Niah Caves, and Puteh Caves). Our record is new for Mt. Penrisen.

Remarks.—*Philippinensis* species group (Csorba et al. 2003). *Rhinolophus philippinensis* was netted near a pond in Mt. Penrisen. Scarcity of records in Borneo suggests this species may be rare. *Rhinolophus philippinensis* is distinguished from other similar species by a FA length of 48-53 mm and by a peculiar noseleaf structure (i.e., wide internarial region and a

horseshoe shape). There are morphological, genetic, and echolocation call variations within this species that are associated with different islands in Indonesia (Kingston and Rossiter 2004). One specimen, TTU 108380 (17 August 2006), was post-lactating.

Rhinolophus robinsoni Andersen 1918
Peninsular Horseshoe Bat
(Kelawar Ladam Semenanjung)

Specimen examined (1).—Krau: TTU 108185 (GenBank EU521611).

Type locality.—Thailand, Surat Thani, Bandon, Kaho Nawng.

Malaysian distribution.—Recorded from Peninsular Malaysia.

Remarks.—*Megaphyllus* species group (Csorba et al. 2003). *Rhinolophus robinsoni* was caught using a harp trap across a walking trail. The noseleaf of *R. robinsoni* lacks lateral lappets and has a rounded connecting process. A diagnostic step-wise constriction at the mid length of sella can be observed (Kingston 2006). Csorba et al. (2003) classified *robinsoni* as a subspecies of *R. megaphyllus* because it had intermediate features with respect to other Asian mainland species. We recognize *R. robinsoni* as a valid species following Simmons (2005) and Francis (2008) because *R. robinsoni* has a restricted geographic distribution and does not overlap with other *R. megaphyllus* subspecies recognized by Csorba et al. (2003).

Rhinolophus sedulus K. Andersen 1905
Lesser Woolly Horseshoe Bat
(Kelawar Ladam Bulu Halus)

Specimens examined (5).—Kubah NP: TTU 108325 (GenBank EU521612), TTU 108341, TTU 108344; Mt. Penrisen: TTU 108394, TTU 108396.

Type locality.—Malaysia (Borneo), Sarawak.

Malaysian distribution.—Recorded from Peninsular Malaysia (all states) and Borneo.

Remarks.—*Trifoliatus* species group (Csorba et al. 2003). *Rhinolophus sedulus* were found roosting

with two *R. luctus* in a culvert at Kubah NP and were caught using a hand net. Due to scarcity of specimens, little is known about this species. *Rhinolophus sedulus* has darkly colored trilobated sella and the smallest forearm length (40–44 mm) compared to other species in the *trifoliatus* species group.

Rhinolophus stheno K. Andersen 1905
Lesser Brown Horseshoe Bat
(Kelawar Ladam Bukit)

Specimens examined (2).—Krau: TTU 108171 (GenBank EU521613), TK 152014.

Type locality.—Malaysia (Peninsular Malaysia), Selangor.

Malaysian distribution.—Recorded from Peninsular Malaysia (all states).

Remarks.—*Megaphyllus* species group (Csorba et al. 2003). *Rhinolophus stheno* was caught using harp traps in Krau within lowland dipterocarp forests. This species has a unique, straight-sided lancet. The median septum is much wider than the middle pockets and the rounded connecting process does not originate from the tip of the sella. Two different subspecies have been recognized within this species, *R. s. stheno* (in Java, Sumatra, Peninsular Malaysia, and Thailand south of the Isthmus of Kra) and *R. s. microglobosus* (in Lao PDR, Vietnam, and Thailand north of the Isthmus of Kra; Csorba et al. 2003). Both of the specimens recorded in this study have the same *cyt-b* gene haplotype.

Rhinolophus trifoliatus Temminck 1834
Trefoil Horseshoe Bat
(Kelawar Ladam Muka Kuning)

Specimens examined (9).—Krau: TTU 108173 (GenBank EU521614), TK 152045, TTU 108205; Monggis: TTU 108238, TK 152098, TTU 108250; Bako NP: TTU 108273, TTU 108275; Kubah NP: TTU 108315.

Type locality.—Indonesia, West Java, Bantam.

Malaysian distribution.—Recorded from Peninsular Malaysia and Borneo.

Remarks.—*Trifoliatus* species group (Csorba et al. 2003). This species was mainly caught using harp traps across trails. *Rhinolophus trifoliatus* can be distinguished easily from other members of the family as it has a distinct yellow noseleaf color. A genetic distance of 0.7% in *cyt-b* gene sequences was observed between Peninsular Malaysia and Borneo samples.

Family Hipposideridae

Hipposideros ater Templeton 1848

Dusky Leaf-nosed Bat (Local name not available)

Specimens examined (2).—Mt. Penrisen: TTU 108379 (GenBank EU521615), TTU 108391.

Type locality.—Sri Lanka, Western Province of Colombo.

Malaysian distribution.—Recorded from Peninsular Malaysia (no specific localities) and Borneo (Sabah: Gomantong, Kinabalu, Madai, Segarong, and Sukau; Sarawak: Bako NP, Bau, Jambusan Cave, Kubah NP, Mt. Murud, and Niah NP). Our record is new for Mt. Penrisen.

Remarks.—*Bicolor* species group (Corbet and Hill 1992). This bat was caught in harp traps set across walking trails beside a stream. *Hipposideros ater* has a pale pinkish noseleaf with no lateral leaflets. Important characters used for identification are forearm size and the internarial septum which is slightly swollen at the base and very narrow in the middle (Hill 1963; Hill and Francis 1984). There is morphological overlap (forearm, ear, and tail length) between *H. ater*, *H. bicolor*, *H. cineraceus*, and *H. dyacorum*. A specimen, TTU 108391 (19 August 2006), from Mt. Penrisen had a facial gland behind the posterior noseleaf (similar to the gland in *H. galeritus*). Low *cyt-b* genetic distance was observed between Borneo samples (< 1%). However, a GenBank sequence of *H. ater* (DQ054807) from Australia has a genetic distance value >5% with respect to our Borneo specimen. The significance of this genetic distance value is limited as this is the only available *cyt-b* gene sequence of *H. ater* for comparison. In light of current findings, it is probable that *H. ater* in Borneo might represent a different taxon as proposed by Suyanto and Struebig (2007).

Hipposideros bicolor (Temminck 1834)

Bicolored Leaf-nosed Bat

(Kelawar Ladam Bulat Biasa)

Specimens examined (20).—Krau: TTU 108417, TK 152015, TTU 108178, TTU 108186, TTU 108189, TTU 108190, TTU 108191, TTU 108192, TTU 108196, TTU 108198, TTU 108199, TTU 108201, TTU 108209, TTU 108222; Bako NP: TTU 108267, TTU 108289, TTU 108294, TTU 108296, TTU 108297, TTU 108301 (GenBank EU521616).

Type locality.—Indonesia, Java, Anjer coast.

Malaysian distribution.—Recorded throughout Southeast Asia including Peninsular Malaysia (all states), and Borneo (Sabah: Gomantong, and Sukau; Sarawak: Bako NP, Fairy Cave, and Jambusan Cave).

Remarks.—*Bicolor* species group (Corbet and Hill 1992). This species was caught in harp traps in small flyways. *Hipposideros bicolor* has a simple noseleaf, lacking leaflets, and a straight internarial septum (Hill 1963; Hill et al. 1986). More than 20 individuals per night were captured in Krau and released after identification, representing the highest total number of specimens of a single species captured at any site. This species was classified into two different phonic types, 131 kHz and 142 kHz, in Peninsular Malaysia (Kingston et al. 2001). A third phonic type of 136 kHz has been recorded in Sarawak (Les Hall, pers. comm.). Although several morphological features have been described to differentiate the ‘131’ and ‘142’ types, some overlap exists among these features and the frequency of echolocation calls seems to be the best discriminator (Kingston et al. 2001). Variation in echolocation call frequency is reflected in *cyt-b* sequences with a genetic distance of 7% between the two phonic types in Peninsular Malaysian populations (Kingston et al. 2001). When these two types were compared to Borneo individuals, genetic distances of 5% (to the 131 type) and 11% (to the 142 type) were observed. The significance of this variation remains to be defined. The only available subspecies name in Borneo is *H. b. bicolor* that is similar to those from Java (type locality), whereas in Peninsular Malaysia it is *H. b. atrox* (Hill et al. 1986). The two phonic types that are found in

Peninsular Malaysia occur sympatrically, suggesting there is at least one unrecognized species within currently designated *H. bicolor* from Malaysia. Specimen TTU 108296 (13 August 2006) was pregnant.

Hipposideros cervinus (Gould 1854)
Fawn-colored Leaf-nosed Bat
(Kelawar Ladam Bulat Gua)

Specimens examined (28).—Krau: TTU 108172 (GenBank EU521617), TK 152007, TTU 108193, TTU 108194, TTU 108195, TTU 108197, TTU 108208, TTU 108220, TTU 108221; Monggis: TTU 108233; Bako NP: TTU 108268, TTU 108269, TTU 108270, TTU 108271, TTU 108288, TTU 108290, TTU 108291, TTU 108292, TTU 108300; Kubah NP: TTU 108316, TTU 108328, TTU 108331, TTU 108332; Mt. Penrisen: TTU 108365, TTU 108367, TTU 108414, TTU 108389, TTU 108392.

Type locality.—Australia, Queensland, Cape York and Albany Island.

Malaysian distribution.—Recorded from Peninsular Malaysia and Borneo.

Remarks.—*Bicolor* species group (Corbet and Hill 1992). *Hipposideros cervinus* is known to forage on small insects in the forest understory and was collected at all study sites using harp traps. Variation in color of dorsal fur was observed among individuals. In the field, *H. cervinus* is easily distinguished from most other Hipposiderids, with the exception of *H. galeritus*. *Hipposideros galeritus* and *H. cervinus* are very similar morphologically, but can usually be distinguished from each other by the longer tail length (30–43 mm) and broader intermediate noseleaf compared to the posterior noseleaf (Hill 1963; Hill 1983; Payne et al. 1985) in *H. galeritus*. Despite differences in color forms there were no substantial morphological differences or *cyt-b* genetic distance values (< 1%) within and between individuals of *H. cervinus* from Peninsular Malaysia and Borneo.

Hipposideros cineraceus Blyth 1853
Ashy Leaf-nosed Bat
(Kelawar Ladam Bulat Terkecil)

Specimens examined (1).—Krau: TTU 108176 (GenBank EU521618).

Type locality.—Pakistan, Punjab, Salt Range, near Pind Dadan Khan.

Malaysian distribution.—Recorded from Peninsular Malaysia (all the states) and Borneo (Sabah: Banturong, Kinabalu, Madai, Marudu Bay, Segarong, and Upper Sungai Kuamut; Sarawak: Bako NP, and Jambusan Cave).

Remarks.—*Bicolor* species group (Corbet and Hill 1992). In Krau and Mt. Penrisen, this species was caught in a harp trap along with *H. bicolor*. *Hipposideros cineraceus* has a pinkish noseleaf without lateral leaflets. Bright pinkish pigments can be observed on rostrum and noseleaf. *Hipposideros cineraceus* is difficult to distinguish using morphology alone as it closely resembles *H. ater* and *H. dyacorum* (Hill 1963; Philips 1967; Hill and Francis 1984). Characteristics that differentiate *H. cineraceus* from *H. bicolor* are a thickened internarial septum in the middle of the noseleaf that forms a slightly raised bump, and a smaller body size (Francis 2008). *Hipposideros cineraceus* is also distinguished from *H. doriae* by the presence of three vertical septa (Francis 2008). Cytochrome-*b* genetic distances of 4.3% and 8.7% were observed between our specimen from Krau (Peninsular Malaysia) to the sequence of specimens from Thailand (TK 21261; specimen in NSRL) and Krau (DQ054809; sequence in GenBank), respectively. These data are congruent with Francis (2008) in that there are at least two potential species within the *H. cineraceus* complex.

Hipposideros coxi Shelford 1901
Cox's Leaf-nosed Bat (Local name not available)

Specimens examined (2).—Bako NP: TTU 108272 (GenBank EU521619); Mt. Penrisen: TTU 108358.

Type locality.—Malaysia (Borneo), Sarawak, Mt. Penrisen (1,280 m).

Malaysian distribution.—Recorded from four localities in Borneo (Sarawak: Bako NP, Bungoh Cave, Jambusan Cave and Mt. Penrisen). This study is the third published record of this species in Sarawak since Payne et al. (1985) and Jub et al. (2003).

Remarks.—*Bicolor* species group (Corbet and Hill 1992). *Hipposideros coxi* was caught in a harp trap near rock crevices in Bako NP and in an open area near a clump of trees at Mt. Penrisen. This species has distinctly dark wings and ears covered with hair. A unique feature in this species is the enlarged noseleaf that covers the muzzle with two lateral leaflets (Payne et al. 1985).

Hipposideros doriae (Peters 1871)

Bornean Leaf-nosed Bat
(Kelawar Ladam Bulat Lawas)

Specimens examined (2).—Mt. Penrisen: TK 152239 (GenBank FJ460489), TTU 108390.

Type locality.—Malaysia (Borneo), Sarawak.

Malaysian distribution.—Recorded from Peninsular Malaysia (Pahang: Gunung Benom, Krau, Tasik Bera; Perak: Maxwell Hill; and Selangor: Hulu Gombak) and Borneo (Sabah: Gunung Emas-Crocker Range; and Sarawak: Lawas). Our record is new for Mt. Penrisen and is the second record for Sarawak. The first record was described as *H. sabanus* Thomas 1898, from Lawas, but today *sabanus* is recognized as a junior synonym of *H. doriae* Peters 1871.

Remarks.—*Bicolor* species group (Corbet and Hill 1992). *Hipposideros doriae* was caught in a harp trap near a small stream and in a net placed across a small pond. This species is distinguished from other similar species by a posterior noseleaf that lacks vertical septa (Benda 2000; Fig. 3a), a slightly concave horseshoe that is swollen in the middle of an internarial septum, and nostrils covered with small lappets. Gray or dark brown pigments can be observed on rostrum and noseleaf. Both Bornean specimens have the same *cyt-b* gene haplotype.

Hipposideros dyacorum Thomas 1902

Dayak Leaf-nosed Bat (Local name not available)

Specimens examined (3).—Kubah NP: TTU 108340 (GenBank EU521620); Mt. Penrisen: TTU 108355, TTU 108384.

Type locality.—Malaysia (Borneo), Sarawak, Baram, Mt. Mulu.

Malaysian distribution.—Recorded from Peninsular Malaysia (Perlis: Kaki Bukit; Pahang: Krau; and restricted areas near Peninsular Thailand) and Borneo (Sabah: Mt. Mulu, Tawau Hill; Sarawak: Bako NP, Bukit Kana, Fairy Cave, Jambusan cave, Kubah NP, Lambir NP, Mt. Hose, and Similajau NP). The specimens from Mt. Penrisen represent a new geographic record.

Remarks.—*Bicolor* species group (Corbet and Hill 1992). All individuals were collected using harp traps set across small forest trails. *Hipposideros dyacorum* is distinguished from similar species *H. ater*, *H. cineraceus*, and *H. bicolor* by their internarial septum, which is expanded in the middle (Philips 1967; Payne et al. 1985). Despite the overlap in size with other similar species noted above, this species has the shortest tail (19–24 mm; Payne et al. 1985).

Hipposideros galeritus Cantor 1846

Cantor's Leaf-nosed Bat
(Kelawar Ladam Bulat Gua)

Specimens examined (9).—Bako NP: TTU 108279 (GenBank EU521621), TTU 108283, TTU 108293, TTU 108302, TTU 108303; Mt. Penrisen: TTU 108354, TTU 108356, TTU 108375, TTU 108416.

Type locality.—Malaysia (Peninsular Malaysia), Penang Island.

Malaysia distribution.—Recorded from Peninsular Malaysia (Kedah: Pulau Singa, Ulu Muda; Negeri Sembilan: Broga; Pahang: Krau, Taman Negara; Perak: Maxwell Hill; Pulau Pinang: Balik Pulau; and Selangor: Bukit Kutu, Hulu Gombak, Hulu Langat) and throughout Borneo. Our specimens constitute a new geographic record for Mt. Penrisen.

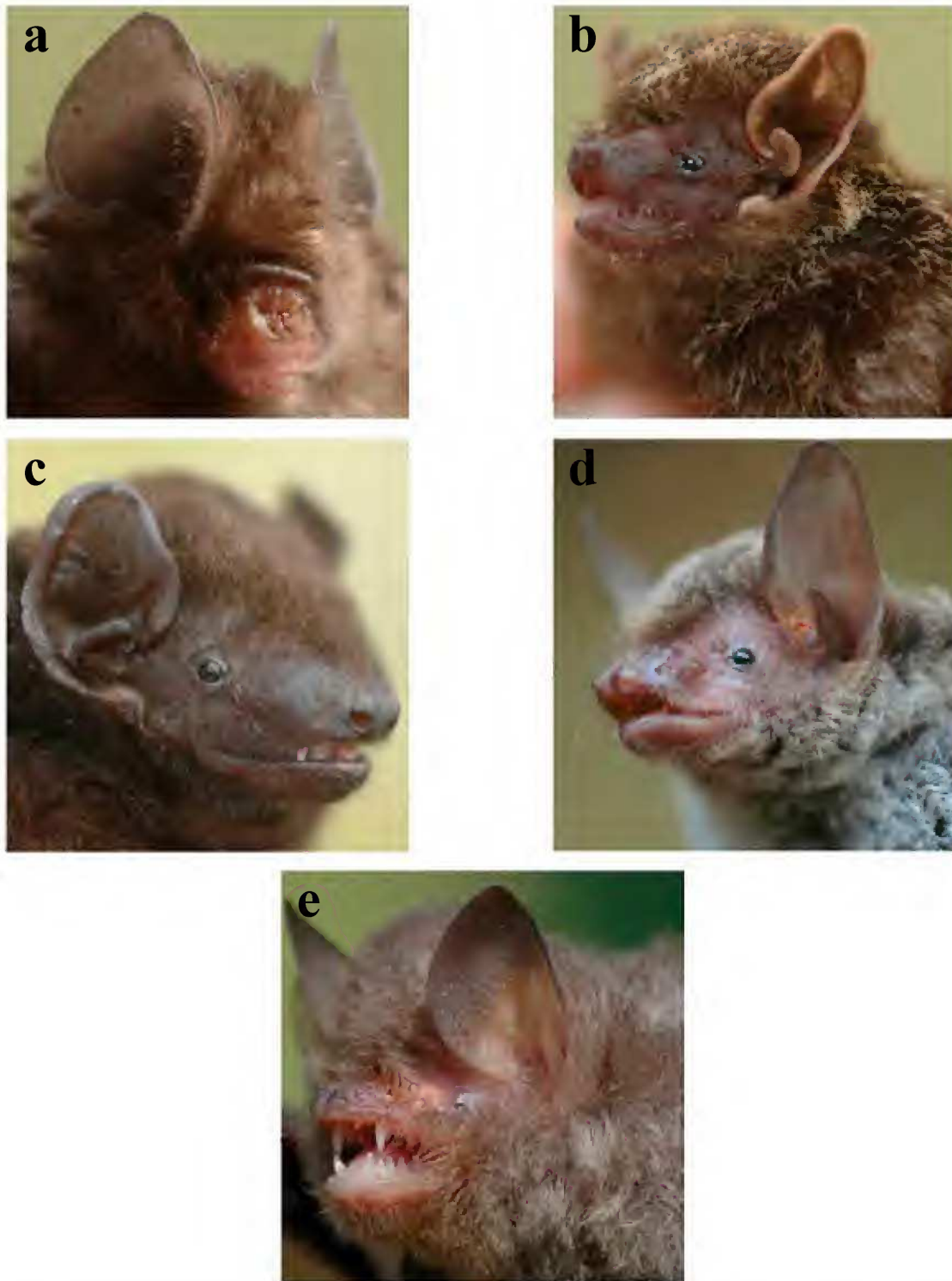


Figure 3. Photo of (a) *Hipposideros doriae* (TK 152239), second confirmed record in Sarawak since 1898. New geographic records for Sarawak: (b) *Arielulus cuprosus* (TTU 108383), (c) *Hesperoptenus tomesi* (TTU 108400), (d) *Myotis adversus* (TTU 108277), and (e) *Kerivoula lenis* (TTU 108210).

Remarks.—*Bicolor* species group (Corbet and Hill 1992). *Hipposideros galeritus* was caught in harp traps along with *H. cervinus*. Field characters that distinguish *H. galeritus* from *H. cervinus* include tail length (30–43 mm in *H. galeritus*; 21–28 mm in *H. cervinus*) and broader median than posterior noseleaf; whereas broader posterior noseleaf exists in *H. cervinus* (Hill 1963). A male *H. galeritus* (TTU 108375; 18 August 2006) from Mt. Penrisen had a facial gland behind the posterior noseleaf (Fig. 4). When pressure was applied to the side of this gland, hair-like structures with green secretions emerged.

Hipposideros larvatus (Horsfield 1823)

Intermediate Leaf-nosed Bat
(Kelawar Ladang Bulat Besar)

Specimens examined (4).—Bako NP: TTU 108274 (GenBank EU521622), TTU 108276, TTU 108281, TTU 108282.

Type locality.—Indonesia, Java.

Malaysia distribution.—Recorded from Peninsular Malaysia (all states) and Borneo (Sarawak: Bako NP, Fairy Cave, Jambusan, Kubah NP, Kuching, Lubok Simpon, Mt. Pueh, and Tanjung Datu NP).

Remarks.—*Larvatus* species group (Corbet and Hill 1992). *Hipposideros larvatus* was caught in harp traps placed across trails and rock crevices. This is the only species collected in our study that has three lateral leaflets (Payne et al. 1985). Taxonomic reviews from morphological and genetic datasets indicate that more than one genetic phylogroup occurs within this species (Kitchener and Maryanto 1993; Thabah et al. 2006). A genetic distance of 3.5% in the *cyt-b* gene was observed between a specimen from China (DQ888672) and our specimen from Borneo.



Figure 4. *Hipposideros galeritus* (TTU 108375) from Mount Penrisen with a facial gland behind the noseleaf (see Tate 1941; Hill 1963; Nowak 1999). In an undisturbed state this gland is nondescript; however, when the lateral sides of the gland are palpated, the inner part of the gland is visible as in this figure.

Hipposideros ridleyi Robinson and Kloss 1911
Ridley's Leaf-nosed Bat
(Kelawar Ladang Bulat Singapura)

Specimens examined (3).—Kubah NP: TK 152188 (GenBank EU521623), TK 152189, TK 152191.

Type locality.—Singapore, Botanic Gardens.

Malaysian distribution.—Recorded from Peninsular Malaysia and Borneo

Remarks.—*Bicolor* species group (Corbet and Hill 1992). *Hipposideros ridleyi* was caught inside a drainage tunnel in Kubah NP using hand nets. This species has a large noseleaf that covers the muzzle without lateral leaflets, and has a disc shaped structure on the nostril (Payne et al. 1985). Comparison with a GenBank sequence (DQ054811) indicated a low *cyt-b* genetic distance (< 2%) between Bornean and Peninsular Malaysian populations.

Family Megadermatidae
Megaderma spasma (Linnaeus 1758)
Lesser False Vampire Bat (Kelawar Telinga Lebar)

Specimens examined (2).—Bako NP: TTU 108285 (GenBank EU521606); Kubah NP: TTU 108347.

Type locality.—Indonesia, Molucca Isls, Ternate.

Malaysian distribution.—Recorded from Peninsular Malaysia and Borneo.

Remarks.—*Megaderma spasma* was collected with harp traps across trails in the forest. Unlike *Nycteris*, *Megaderma* has long ears that are connected at the base (Payne et al. 1985), a long noseleaf with convex sides, and no tail. A comparison to a GenBank sequence from Java, Indonesia (AY057942), were about 0.4 to 2% *cyt-b* genetic distance, suggesting individuals we captured in Borneo probably represent *M. spasma* whereas others specimens compared here need to be reevaluated.

There are two species in this genus recognized within Malaysia: *M. lyra* and *M. spasma*. Morphologically, *M. lyra* (FA: 60-71 mm) differs in noseleaf shape and narial emargination of skull compared to *M. spasma* (FA: 52-63 mm) (Corbet and Hill 1992). Genetically, we have compared the *cyt-b* sequences of specimens identified as *M. spasma* from Thailand (TK 21322 and TK 21323) to our specimens from Borneo and found a genetic distance of 10-12% separates the two. Additionally, when we compared our specimens to individuals identified as *M. lyra* in GenBank (DQ888678: China and DQ680822: India), a genetic distance of 20-21% separated *lyra* from *spasma*. Specimens from Thailand or those in GenBank may actually represent *M. lyra*, but this hypothesis remains to be tested, as the voucher specimens were unavailable for examination.

Family Emballonuridae
Subfamily Taphozoinae
Saccolaimus saccolaimus (Temminck 1838)
Naked-rumped Pouched Bat
(Kelawar Dada Putih)

Specimens examined (2).—Bako NP: TTU 108286 (GenBank EU521626), TTU 108295.

Type locality.—Indonesia, Java.

Malaysian distribution.—Recorded from Peninsular Malaysia (all states) and Borneo (Sabah: Kenningau, Kota Kinabalu, and Tenom; Sarawak: Bako NP, Kampung Tanah Putih, Kuching, Lundu, Samunsam, and Taman Sukma).

Remarks.—This species was collected using mist nets in front of a dead mangrove tree where the bats were found roosting. Individuals of *Saccolaimus saccolaimus* usually fly above the canopy and roost in tree branches or rock crevices. Diagnostic characters distinguishing this species include: absent to poorly developed metacarpal pouch, glandular pouch under the chin, and narrow whitish (almost translucent) wings (Francis 2008). Both specimens collected in this study have the same *cyt-b* gene sequence haplotype.

Subfamily Emballonurinae

Emballonura alecto (Eydoux and Gervais 1836)

Small Asian Sheath-tailed Bat

(Kelawar Teng-Teng Ceteng Kecil)

Specimens examined (4).—Kubah NP: TTU 108335 (GenBank EU521625), TTU 108336, TTU 108337; Mt. Penrisen: TTU 108405.

Type locality.—Philippines, Luzon, Manila.

Malaysian distribution.—This species is known from three localities (Sabah: Poring, and Tawau Hill; Sarawak: Bako NP). Our specimen from Mt. Penrisen is a new geographic record.

Remarks.—*Emballonura alecto* was caught using hand nets in a culvert at Kubah NP and with a harp trap near the forest edge at Mt. Penrisen. Specimens are uniformly dark brown to black with long grayish fur. There is morphological overlap between *E. alecto* and *E. monticola*, however a short gap between the first and second upper premolars is present in *E. alecto* and absent in *E. monticola* (Corbet and Hill 1992). There is less than 1% genetic divergence within our *E. alecto* samples from Borneo. Comparison of our *E. alecto* *cyt-b* gene sequences from Borneo to *E. monticola* from Thailand (EF584233) resulted in a genetic distance of 9.2%. Specimen TTU 108405 (19 August 2006) was post lactating.

Family Nycteridae

Nycteris tragata (K. Andersen 1912)

Malayan Slit-faced Bat (Kelawar Muka Lekok)

Specimen examined (1).—Krau: TTU 108180 (GenBank EU521624).

Type locality.—Malaysia (Borneo), Sarawak, Bidi caves.

Malaysian distribution.—Recorded from Peninsular Malaysia (all states) and Borneo.

Remarks.—*Javanica* species group (Van Cakenberghe and De Vree 1930). A single individual was collected using harp traps near a walking trail. This is the only species from this family occurring in Malaysia. *Nycteris tragata* has a long tail and ears that are separated from each other at the base (distinguishing

characters between Megadermatidae and Nycteridae); and a slit is present in the middle of the rostrum. Our Peninsular Malaysian specimen was separated by a genetic distance of 2.3% when compared to Borneo sequences obtained from UNIMAS collections.

Family Vespertilionidae

Subfamily Vespertilioninae

Arielulus cuprosus (Hill and Francis 1984)

Coppery Sprite (Local name not available)

Specimens examined (2).—Mt. Penrisen: TTU 108383 (GenBank EU521631), TTU 108397.

Type locality.—Malaysia (Borneo), Sabah, Sepilok (05°52'N, 117°56'E).

Malaysian distribution.—Recorded from Sabah, Sepilok. A new geographic record was added for Mt. Penrisen and for the state of Sarawak.

Remarks.—Tribe Nycticeiini (Hooper and Van Den Bussche 2003). *Arielulus cuprosus* was caught using harp traps across a walking trail at Kubah NP and in mist nets along the edge of a steep cliff at Mt. Penrisen. This species has long, and thick, upper fur with black bases and red orange (coppery) tips (Fig. 3b). Most of the published literature and museum databases have classified *A. cuprosus* in the genus *Pipistrellus* or *Eptesicus*. Four specimens referred as “*Pipistrellus cuprosus*” from Kubah NP (four individuals) and Similajau NP (one individual) are in the UNIMAS museum database. Although not examined by us, these are likely to be *Arielulus cuprosus* and therefore we have included Kubah NP and Similajau NP as part of the distribution of *A. cuprosus*. This is a new distribution record for Sarawak.

Hesperoptenus tomesi Thomas 1905

Large False Serotine (Kelawar Petang Palsu)

Specimen examined (1).—Mt. Penrisen: TTU 108400 (GenBank EU521633).

Type locality.—Malaysia, Malacca.

Malaysian distribution.—Recorded from Peninsular Malaysia (Malacca: Asahan; Selangor: Cameron Highlands, Genting Highlands, Mt. Brinchang; and Perak: Maxwell Hill) and Borneo (Sabah: Sandakan

Bay, and Tabin). A new geographic record was added for Mt. Penrisen and for the state of Sarawak.

Remarks.—Tribe Nycticeini (Hooper and Van Den Bussche 2003). *Hesperoptenus tomesi* was caught along the edge of a steep cliff using mist nets. This specimen was identified by forearm size of 50-53 mm, a rounded head, and sloping forehead (Payne et al. 1985). Other external characters for this genus include rounded, short ears and a slightly hatchet-shaped tragus. The dorsal and ventral sides of our specimen are uniformly dark blackish brown (Fig. 3c).

Glischropus tylopus (Dobson 1875)
Common Thick-thumbed Bat
(Kelawar Tapak Tangan Putih)

Specimens examined (14).—Monggis: TTU 108229 (GenBank EU521632), TTU 108239, TTU 108243, TK 152089, TTU 108244, TTU 108253, TTU 108255, TTU 108256, TTU 108260, TTU 108264; Kubah NP: TTU 108311; Mt. Penrisen: TTU 108368, TTU 108370, TTU 108398.

Type locality.—Malaysia (Borneo), Sabah.

Malaysian distribution.—Recorded from Peninsular Malaysia and Borneo.

Remarks.—Tribe Pipistrellini (Hooper and Van Den Bussche 2003). This species was caught mainly in harp traps set near bamboo trees. Their unique character is the unpigmented white to pink pad on the thumb and sole of foot that may facilitate their movement inside broken bamboo trees. Specimens have dark brown upperparts and pale buffy brown underparts. Low *cyt-b* genetic distance (< 1%) was observed between *G. tylopus* from different localities in Borneo.

Pipistrellus stenopterus (Dobson 1875)
Narrow-winged Pipistrelle (Kelawar Malam Kecil)

Specimens examined (2).—Monggis: TTU 108236 (GenBank EU521634); Mt. Penrisen: TTU 108399.

Type locality.—Malaysia (Borneo), Sarawak.

Malaysian distribution.—Recorded from Peninsular Malaysia (Johore: Endau Rompin; Kedah: Pulau Singa; Negeri Sembilan: Serting; Pahang: Krau, Lakum, Sungai Relau, Taman Negara; Perak: Grik; and Selangor: Bukit Kutu, Bukit Lagong, Hulu Gombak) and Borneo (Sabah: Kota Kinabalu, Mt. Trus Madi, Poring, and Sandakan; Sarawak: Kelabit uplands, and Kuching).

Remarks.—Tribe Pipistrellini (Hooper and Van Den Bussche 2003). The specimen from Monggis was captured using a hand held mist net while it was hawking insects near a lamp in front of the Monggis station headquarters. The specimen from Mt. Penrisen was collected in a mist net along the edge of a steep cliff. These bats have brown to orange upper and underparts.

Tylonycteris robustula Thomas 1915
Greater Bamboo Bat (Kelawar Buluh Besar)

Specimens examined (3).—Monggis: TTU 108237; Kubah NP: TTU 108309; Mt. Penrisen: TTU 108386 (GenBank EU521635).

Type locality.—Malaysia (Borneo), Upper Sarawak.

Malaysian distribution.—Recorded from Peninsular Malaysia and Borneo.

Remarks.—Tribe Vespertilionini (Hooper and Van Den Bussche 2003). This species was caught mainly in harp traps near bamboo trees. The unique character of this species is the large, dark brown, flattened, disc-like pad on the thumb and sole of foot (different from those in *G. tylopus*; see above). Along with a flattened head and body, these pads might facilitate their movement inside hollow bamboo stems. They have dark brown upperparts and slightly paler underparts. *Tylonycteris robustula* is morphologically similar to *T. pachypus* which has a smaller greatest skull length of 10.4-10.6 mm compared to 12.3-12.7 mm in *T. robustula*. Low *cyt-b* genetic distance (< 1%) was observed between *T. robustula* from different localities in Borneo.

Subfamily Myotinae

Myotis adversus (Horsfield 1824)

Large-footed Myotis (Kelawar Kaki Panjang)

Specimens examined (3).—Bako NP: TTU 108277 (GenBank EU521628), TTU 108278, TTU 108307.

Type locality.—Indonesia, Java.

Malaysian distribution.—Records from Peninsular Malaysia and other parts of the Asian mainland remain uncertain (Francis 2008). In Sabah, this species is known only from Sandakan Bay (Payne et al. 1985). A new geographic record was added for Bako NP and for the state of Sarawak.

Remarks.—This species was captured in a harp trap and a mist net across a small stream between swamp forest and the beach. As the common name implies, *M. adversus* has a large foot with a wing membrane inserted at the ankle (Hill 1983; Kitchener et al. 1995; Fig. 3d). *Myotis adversus* also has a unique translucent wing membrane. A high genetic distance of 15.2% was documented when the Sarawak specimens were compared with a GenBank *cyt-b* gene sequence (AB106587; see Kawai et al. 2003) from Taiwan. Based on geographic distribution, our specimen would represent *M. adversus carinatae* and that from Taiwan should correspond to *M. adversus taiwanensis* (see Kitchener et al. 1995). However, the level of genetic variation suggests that these should be elevated to species status.

Myotis muricola (Gray 1846)

Nepalese Whiskered Myotis (Kelawar Daun Pisang)

Specimens examined (5).—Kubah NP: TTU 108310 (GenBank EU521629), TTU 108314; Mt. Penrisen: TTU 108369, TTU 108403, TTU 108404.

Type locality.—Nepal.

Malaysian distribution.—Recorded from Peninsular Malaysia and Borneo.

Remarks.—This species was collected over small ponds in Kubah NP and in Mt. Penrisen using

mist nets. The upperparts are brown to gray with dark bases and the underparts are broadly buffy white with pale gray tips. The wing membrane is attached to the toe (Hill 1983). In comparison to our specimens, high *cyt-b* genetic distances, from 6.8% (AY665144, locality unknown) to 18.2% (AJ841957 from Laos) were observed, indicating more than one species may be present under this name (see Hendrichsen et al. 2001; Francis et al. 2008).

Myotis ridleyi Thomas 1898

Ridley's Myotis (Kelawar Kecil)

Specimens examined (8).—Krau: TTU 108179 (GenBank EU521630), TTU 108184, TTU 108187, TTU 108188, TTU 108200, TTU 108202, TTU 108203, TTU 108204.

Type locality.—Malaysia, Selangor, Kepong.

Malaysian distribution.—Recorded from Peninsular Malaysia and Borneo.

Remarks.—*Myotis ridleyi* was found roosting in small groups. All the specimens were captured using hand nets inside a culvert near Krau headquarters. *Myotis ridleyi* has small feet with the wing membrane attached to the side of the foot (Medway 1978). This species can be distinguished from similar species using a forearm size of 27–32 mm (Francis 2008).

Subfamily Murinae

Murina rozendaali Hill and Francis 1984Gilded Tube-nosed Bat
(Kelawar Hidung Bulu Merah)

Specimens examined (2).—Krau: TTU 108216; Monggis: TTU 108241 (GenBank EU521627).

Type locality.—Malaysia (Borneo), Sabah, Gomantong.

Malaysian distribution.—Recorded from Peninsular Malaysia (Pasoh, Negeri Sembilan; Krau, Pahang) and Borneo (Sabah: Gomantong Cave, Poring, and Tepadong; Sarawak: Bukit Kana, Kubah NP, and Mt. Murud).

Remarks.—*Murina rozendaali*, caught using harp traps, is difficult to distinguish from *M. aenea* and *M. suilla* (Francis 1997). Our specimens have upperparts with dark bases and golden tips whereas underparts are white to the bases with a buffy tinge. We conclude that our specimen represents *M. rozendaali* as it was collected in similar habitat (disturbed lowlands over a small stream) and falls within described external measurements (Payne et al. 1985).

Subfamily Kerivoulinae

Kerivoula hardwickii Horsfield 1824
Hardwicke's Woolly Bat (Kelawar Hutan)

Specimens examined (4).—Monggis: TTU 108235 (GenBank EU188768), TTU 108249, TTU 108263; Bako NP: TTU 108298.

Type locality.—Indonesia, Java.

Malaysian distribution.—Recorded from Peninsular Malaysia and Borneo.

Remarks.—*Kerivoula hardwickii* was collected using harp traps near streams and fragmented forest. Historically, this species has been confused with *K. pellucida* (Tomes 1858), however the wings of *K. hardwickii* are not as translucent as those of *K. pellucida*. *Kerivoula hardwickii* also has a less globular braincase, with a wider posterior palate extension. Our specimens have dark gray fur and long ears, whereas *K. pellucida* has orange-brown fur and smaller ears.

Kerivoula intermedia Hill and Francis 1984
Small Woolly Bat (Local name not available)

Specimens examined (3).—Krau: TK 152019 (GenBank EU188789), TTU 108181, TTU 108217.

Type locality.—Malaysia (Borneo), Sabah, Lumerao.

Malaysian distribution.—Recorded from Peninsular Malaysia (Pahang: Krau) and Borneo.

Remarks.—This species was captured using harp traps along with *K. papillosa* and *K. minuta* in Krau. It is slightly larger, with wider ears, and lacks the conspicuous banding (dark bases) of dorsal fur

when compared to *K. minuta*. We originally assigned our specimens to *K. whiteheadi* based on the presence of an elongate P2 (following Corbet and Hill 1992). Subsequently, we learned that *K. whiteheadi* has a more elongate muzzle, with premolars that are oval in cross section and nearly twice as long as they are wide (C. M. Francis, pers. comm.). These characteristics were not obvious in our specimens. *Kerivoula intermedia* is difficult to distinguish from *K. minuta* as the unique character separating them is size. Genetic distance value of 17.26% in *cyt-b* gene between *K. intermedia* and *K. minuta* suggests that genetic data is crucial to provide better discrimination between these species.

Kerivoula lenis Thomas 1916
Lenis Woolly Bat (Local name not available)

Specimens examined (2).—Krau: TTU 108210 (GenBank EU188772); Kubah NP: TTU 108326.

Type locality.—India, Calcutta.

Malaysian distribution.—The current study provides the first confirmed record of this species in both Peninsular Malaysia and Borneo. The distribution of *K. lenis* partially overlaps that of *K. papillosa*, a larger species of *Kerivoula*.

Remarks.—*Kerivoula lenis* was caught using harp traps in habitat similar to where *K. papillosa* and *K. intermedia* were captured. This species was recently recognized as a valid species from the *K. papillosa* complex through morphological evaluations (Vanitharani et al. 2003; Fig. 3e). *Kerivoula lenis* has a genetic distance of 3.92% in the *cyt-b* gene sequence data between individuals from Peninsular Malaysia and Borneo. See *K. papillosa* account for details.

Kerivoula minuta Miller 1898
Least Woolly Bat (Kelawar Hutan Terkecil)

Specimens examined (6).—Krau: TTU 108182 (GenBank EU188774); Monggis: TTU 108230, TTU 108234; Kubah NP: TTU 108339; Mt. Penrisen: TTU 108351, TTU 108415.

Type locality.—Thailand, Trang Province, Lay Song Hong.

Malaysian distribution.—Recorded from Peninsular Malaysia (Kedah: Ulu Muda; Pahang: Lakum, Taman Negara; Perak: Maxwell Hill; and Selangor: Hulu Gombak, Hulu Langat) and Borneo (Sabah: Gomantong, Madai, Pulau Balembangan, Tabin, Tawau, and Wittti Range; Sarawak: Lambir NP, and Mt. Penrisen).

Remarks.—*Kerivoula minuta* was caught in harp traps across walking trails and less effectively in mist nets across small closed ponds. This species has small ears (9–11.5 mm), dorsal hairs with bases dark-brown for almost one-third of their length, and light brown tips. *Kerivoula minuta* has a short forearm (FA < 30.5 mm), dark wing membranes and uropatagium, and the proximal dorsal half of the uropatagium has sparse, long, golden brown hairs. A new species, *K. krauensis* (Francis et al. 2007) described from Peninsular Malaysia that occurs in sympatry with *K. minuta*, can be distinguished by fur coloration (dorsal hairs with dark-brown bases for almost one-third of their length with tips light brown in *K. minuta*). *Kerivoula minuta* also occurs with *K. intermedia* and is easily misidentified as *K. intermedia* because the only character to differentiate between them is size. A genetic distance of 4.48% in the *cyt-b* gene was observed between Peninsular Malaysian and Bornean populations of *K. minuta*.

Kerivoula papillosa (Temminck 1840)
Papillose Woolly Bat (Kelawar Hutan Besar)

Specimens examined (4).—Krau: TK 152020 (GenBank EU188782), TTU 108218, TTU 108219, TTU 108183.

Type locality.—Indonesia, Java, Bantam (restricted by Tate, 1940).

Malaysian distribution.—Recorded from Peninsular Malaysia (all states) and Borneo.

Remarks.—*Kerivoula papillosa* was captured using harp traps set along a walking trail. This species is the largest *Kerivoula* species (FA: 38–49 mm) recorded in this study and this measurement distinguishes it from other species in the genus. Previous literature suggested that *K. papillosa* might have included *K. lenis*, which occurs in broad sympatry with *K. papillosa* (Vanitharani et al. 2003). However, *K. lenis* has smaller body size

than *K. papillosa* (Vanitharani et al. 2003) and our study documented a genetic distance of 10% between these species in the *cyt-b* gene. Specimens of *K. papillosa* have a geographic variation of 3.24% in the *cyt-b* gene between Peninsular Malaysia and Borneo.

Kerivoula pellucida (Waterhouse 1845)
Clear-winged Woolly Bat (Kelawar Kepak Jernih)

Specimen examined (1).—Krau: TTU 108213 (GenBank EU188788).

Type locality.—Philippines.

Malaysian distribution.—Recorded from Peninsular Malaysia and Borneo.

Remarks.—*Kerivoula pellucida* was caught using a harp trap set across a forest trail. Several unique characters were observed in this species: orange to pinkish facial coloration, glandular swelling on the tail of male specimens, and translucent wings. Caution needs to be taken when determining the degree of translucency, as it is best done by comparison between specimens of each species. *Kerivoula pellucida* has a genetic distance of 1.29% in the *cyt-b* gene between individuals from Peninsular Malaysia and Borneo.

Family Miniopteridae
Miniopterus magnater Sanborn 1931
Western Long-fingered Bat
(Kelawar Jari Panjang Besar)

Specimen examined (1).—Monggis: TTU 108242 (GenBank EU521636).

Type locality.—Papua New Guinea, E Sepik, Marienberg.

Malaysian distribution.—Recorded from Peninsular Malaysia (uncertain locality) and Borneo (Sabah: Gomantong Cave, Madai, Mt. Kinabalu, Poring, Tawau Hills, and upper Sungai Kuamut).

Remarks.—*Miniopterus magnater* was caught using a hand held mist net when it was hawking insects around lights near the Monggis station headquarters. Cranial measurements were used to identify this species (Hill 1983; Corbet and Hill 1992). Characters

used to identify this species in the field are subtle and this species is usually confused with *Miniopterus schreibersii* (see Hendrichsen et al. 2001). Comparison with available GenBank sequences showed that this species aligned closely with *M. schreibersii* and

M. magnater. A genetic distance of 0.7% in the *cyt-b* gene sequence variation was observed between our specimen and an individual from China (EF517308) available on Genbank.

CONTRIBUTION TO MALAYSIAN CHIROPTEROLOGY

A total of 259 bats was collected from Malaysia in 15 nights of trapping. We collected at least 50 of the known 125 Malaysian bat species. Collection of this many species with their respective genetic material and georeferenced voucher specimens represents a valuable contribution to understanding the biodiversity and species limits of the Malaysian bat fauna. Furthermore, this collaborative effort between the Universiti Malaysia Sarawak and Texas Tech University resulted in tissues from all individuals being archived at both universities, which better protects these valuable resources. Karyotypic data from 169 individuals are archived at Texas Tech University, which further enhances the value of these collections. It is our position that similar collecting trips with properly prepared voucher specimens housed in accredited mammalian museum collections will be a powerful tool in understanding the mammalian fauna of the world. Our collecting trip was designed to address this need and to contribute toward building a strong collaborative relationship between UNIMAS and TTU.

It is hypothesized that ultimately there will be a genetic profile for all species of mammals (Baker and Bradley 2006). But for this to happen, substantial fieldwork is required which embraces the standard of georeferenced classical museum voucher specimens with tissues for genetic studies, as well as associated life history data (e.g., parasites). Classically, field parties have prepared voucher specimens that were returned to museums. Over months and years, these museum vouchers were compared with Linnaean descriptions and taxonomic revisions to produce a faunal list for the geographic area visited as well as the results for that particular expedition(s). This process is still the foundation for faunal lists; however, another type of database is rapidly becoming available. Presently, for mammals this consists of sequencing a mitochondrial gene, usually *cyt-b* (this is the most sequenced gene

in the class Mammalia), and searching GenBank to investigate genetic distances within and between all individuals studied. Comparable to the magnitude of morphological divergence between voucher specimens, genetic data provide an independent dataset to test for species presence/absence and species boundaries (Mayer et al. 2007). Avise and Walker (1999) introduced the perspective that most vertebrate species defined by morphology alone consist of genetically defined phylogroups that potentially represent unrecognized biodiversity. This perspective of phylogroups was placed in the conceptual context of speciation by the Bateson-Dobzhansky-Muller (BDM) model to provide criteria for mammalian populations meriting additional study by Baker and Bradley (2006). Our work indicates that at least nine species (refer to species accounts) that were hypothesized to be conspecific on Peninsular Malaysia and Borneo have genetic distance values suggesting the presence of at least two genetic species. These conspecifics should be further evaluated, first using morphology to avoid misidentification and then, as possible cryptic species groups, through both genetics and morphology. Such an approach will provide increased accuracy in documenting local bat diversity in Malaysia (Baker and Bradley 2006; Mayer et al. 2007).

Multiple reasons exist to collect over many different ecological conditions. In this study, 22 species were found at a single locality, 15 species were found at two localities, six were found at three localities, three in four localities, and one at all five localities sampled. Collecting a particular species from many localities provides stronger support that this species is widely distributed and is common, compared to collecting a particular species from a single site. At a single site a species may not be detected as often as other species due to specific habitat requirements, seasonal effects, or lack of trapping effort. As many species are included in

endangered lists (IUCN 2007), field data obtained from different localities provides information to reevaluate a particular species' taxonomic status and distribution to reassess conservation status.

We collected 67 individuals representing 18 species in Krau, 41 individuals representing 13 species in Monggis, 40 individuals representing 13 species in Bako NP, 41 individuals representing 18 species in Kubah NP, and 70 individuals representing 27 species in Mt. Penrisen. Despite the short sampling period, there were 23 new locality records; Krau Wildlife Reserve: *Kerivoula lenis*, *K. minuta*; Bako National Park: *Myotis adversus*; Kubah National Park: *Hipposideros ridleyi*, *Kerivoula lenis*, *K. minuta*, *Tylonycteris robustula*; Mount Penrisen: *Arielulus cuprosus*, *Emballonura alecto*, *Glischropus tylopus*, *Hesperoptenus tomesi*, *Hipposideros ater*, *H. doriae*, *H. dyacorum*, *H. galeritus*, *Myotis muricola*, *Pipistrellus stenopterus*, *Rhinolophus affinis*, *R. borneensis*, *R. luctus*, *R. philippinensis*, *R. sedulus*, and *Tylonycteris robustula*. A taxonomic list of the specimens collected during the TTU-UNIMAS Sowell Expedition along with conservation status, collecting locality, and associated measurements (Appendix) is available for download as supplementary material at <http://www.nsrll.ttu.edu/publications/opapers.htm>.

This expedition has resulted in four new geographic records for Sarawak: *Arielulus cuprosus*,

Kerivoula lenis, *Myotis adversus*, and *Hesperoptenus tomesi* (Fig. 3); and a second record since 1898 for *Hipposideros doriae* in Sarawak (Fig. 3). A clump of earwigs (Dermaptera: Chelisochidae; *Scizochelisoches* sp.) were recorded on the dorsal side of a female *Eonycteris major* (Fig. 2). These earwigs currently are being studied by members of our team. Earwigs from the same family were previously found on *Eonycteris spelaea* (McClure et al. 1967; Robinson and Marshall 1999) and were thought to ride on this bat while possibly consuming small ectoparasites, shed skin, and perhaps the bats' feces. In addition, our study documented facial glands on male *Hipposideros* species (Fig. 4). Hill (1963) recognized this gland as a "frontal sac" that is usually less developed in female specimens than in males, whereas Tate (1941) suggested this may be a sexual dimorphic character. Although previous literature has mentioned this gland (e.g., Tate 1941; Hill 1963; Nowak 1999), no study has been conducted to further investigate its function and structure.

The amount of variation found in both genetic and morphological data collected on bats within Peninsular Malaysia and Borneo reveal there is more variation than previously documented. Broader sampling including other mainland areas and islands will provide a better understanding of the biodiversity and biogeography of Southeast Asian bats.

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Addresses of authors:

**FAISAL ALI ANWARALI KHAN, VICKI J. SWIER,
SERGIO SOLARI, PETER A. LARSEN,
AND ROBERT J. BAKER**

*Department of Biological Sciences and
Natural Science Research Laboratory, Museum
Texas Tech University
Lubbock, TX 79409-3131 USA
faisal.anwarali@ttu.edu, vicki.swier@ttu.edu, peter.
larsen@ttu.edu, robert.baker@ttu.edu*

*Current address of Sergio Solari:
Instituto de Biología
Universidad de Antioquia
Calle 67 N° 53-108 / AA 1226
Medellín, COLOMBIA
ssolari@matematicas.udea.edu.co*

**BESAR KETOL, WAHAP MARNI, AND
MOHAMMAD TAJUDDIN ABDULLAH**

*Department of Zoology
Faculty of Resource Science and Technology
Universiti Malaysia Sarawak
94300 Sarawak, MALAYSIA
bketol@frst.unimas.my, wmarni@frst.unimas.my, ab-
dullahmt@gmail.com*

SIVANATHAN ELLAGUPILLAY

*Department of Wildlife and National Parks
KM 10 Jalan Cheras
56100 Kuala Lumpur MALAYSIA
siva@wildlife.gov.my*

MAKLARIN LAKIM

*Kinabalu National Park
Sabah, MALAYSIA
marklarin@yahoo.com*